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BRASSICA CROSSES.

By

ARTHUR W. SUTTON, F.L.S., V.M.H.

A Lecture Delivered
Before the Linnean Society,
January 16th, 1908.

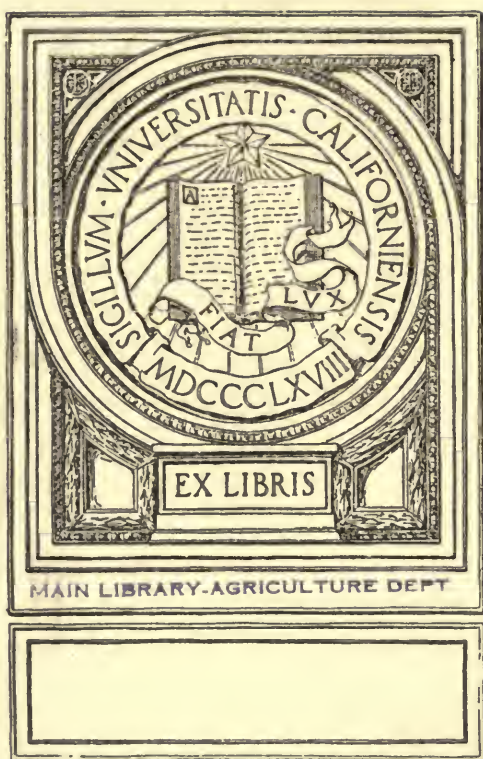
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The Effects of Radio-active Ores and Residues on Plant Life.

BY

MARTIN H. F. SUTTON, F.L.S.

A Report of
THE SECOND SERIES OF EXPERIMENTS,
carried out at Reading, 1915.



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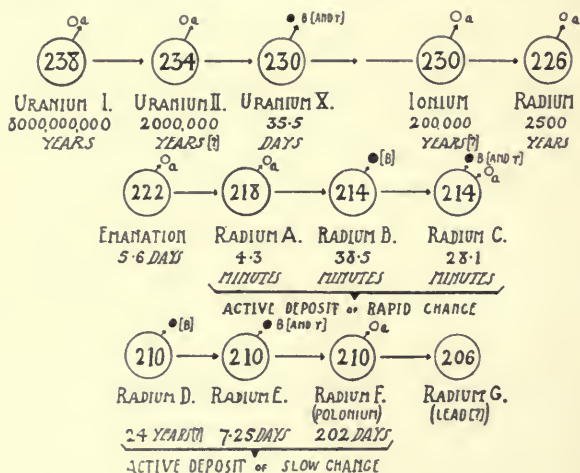
A portion of the Trial Plots dressed with Radio-active Ores at
Sutton's Experimental Station, Reading.

By kind permission of J. Macdonald Brown, Esq., M.D., F.R.C.S., F.R.S.E., the following extracts from his Lecture on "Radium and its Therapeutics" are reprinted from the *Pharmaceutical Journal and Pharmacist* of March 18, 1916:—

"The changes which take place in radium itself during some thousand years of incessant warfare and bombardment are of necessity almost impossible to estimate, but we do know that it changes into some eight intermediate bodies (Radium, A, B, C, D, E, F, G), most of which have only a very short duration of life, and each of which is formed from the preceding one with an outburst of explosive energy and changes into the next with another outburst of energy." (Soddy). Its energy being well over a million times that furnished by the combustion of coal. And just as radium is the parent of the emanation and the subsequent forms, so uranium is the parent of radium, with probably the intermediate ionium between.

"Beyond the emanation stage we have noted subsequent transformations—radium, A, B, etc.—until we eventually arrive at Rf, which is the element polonium, and Rg, which is the metal lead.

"The accompanying diagram, taken from Professor Soddy's work, shows, 'so far as it is at present known, the complete disintegration series of uranium'—



"It will be noticed in the above diagram that wherever the alpha particles—viz., the atoms of helium—are given off, the succeeding body loses four points in its atomic weight.

"Thus is shown the transmutation of the elements. What further transformations take place, as they probably do beyond lead, of these we are as yet ignorant.

"As Sir Robert Ball says, 'the discovery of radium marks an epoch in the history of our knowledge of nature.'

"In the long millions of years which succeeded the Nebular stage in the formation of our world—during these æons of time titanic forces were at work, and gigantic transformations of matter must have taken place.

"It is quite possible to conceive that in those ancient epochs our globe may have been a smelted mass of some protean mineral, from whose evolutions and transformations during immense periods of time our elements as we now know them were gradually segregated and their characteristics specialised.

"We have seen that the older teaching of chemistry received a rude shock as regards its atomic theory by the advent of radium. Again, its fundamental dogma as to the question of unchangeable elements has been shaken, if not shattered, by the even small ray of light which has been shed upon the subject by radium and its transformations.

"In this connection one might even venture to enter upon almost transcendental speculation as to whether indeed any so-called element is ever an absolutely stable and unchanging form of matter, and not merely a stage in matter whose transformations take thousands or millions of years to be carried out.

"The fact is that the greatest scientists and philosophers withal are but as little children struggling and striving for the light, and to whom a few beams have been vouchsafed—beams which only serve to show how colossal our ignorance is of the past no less than the future history of the development of our planet.

"What use may be made in the future of the vast stores of imprisoned energy possessed by our globe, who can foretell? Probably long before the coal measures of the world are exhausted these stores may be being utilised for the production of heat, applied mechanics, etc., etc."

RÉSUMÉ OF THE 1914 EXPERIMENTS.

In my report of the Experiments with radio-active Ores carried out at Reading in 1914 (Bulletin No. 6) I explained at some length the reasons which led to instituting these tests. Briefly, these were :—

The great value of Radium in the successful treatment of certain forms of human disease having been established, it had been freely suggested that its remarkable properties might prove beneficial to plant life. Further, a report reached me that in Cornwall some very fine crops had been obtained from poor garden ground, as the result of dressing the land with soil which had been removed from a neighbouring Radium mine. In order to gain more definite particulars I visited the district in question, but as the incident had occurred a year or so previously I was unable to examine the results. The information I gathered, however, convinced me of the desirability of undertaking, in the interests of scientific research, a series of controlled experiments on a comprehensive scale.

The first difficulty was that of obtaining radio-active Ores, but this having been surmounted, another presented itself in the question of fixing the degree of strength in which to use them. As at that period no controlled experiments had, so far as I was aware, been conducted in this country, I had no reliable data to work upon, and consequently had to more or less feel my way. I therefore decided on proportions varying from 1 part Ore to 12 parts soil, to 1 part Ore to 2,240 parts soil, and to test them (a) thoroughly incorporated in the soil, and (b) placed in a layer at the bottom of a pot or box.

The radio-active Ores used in 1914 were :—

Ore A—containing approximately 8 milligrammes of Radium Bromide per ton of Ore.

Ore B—containing approximately 9 milligrammes of Radium Bromide per ton of Ore.

Slime, or Mine Residue—containing approximately 1.8 milligrammes of Radium Bromide per ton.

The subjects selected for experiment were Radishes, Lettuces, Peas, and Flowering Annuals, in addition to which germination tests were made with seeds of Rape, Red Clover and Smooth-stalked Meadow Grass.

All that was attempted was to ascertain :—

- (1) Whether radio-activity has a harmful or beneficial effect upon plant life ;
- (2) Whether, if beneficial, strong or weak dressings of radio-active Ore should be employed ; and
- (3) Whether radio-active material can be used with advantage to accelerate germination.

The conclusions to which I came are outlined in the following brief summary of the experiments :—

Whilst not pretending that the results of a single season's experiments, embracing only a few subjects, can be regarded as sufficiently definite to prove the value, or otherwise, of the effects of Radium on plant life in general, the tests afford some evidence that Radium possesses the property of developing and increasing growth.

Many of the Radish, Lettuce and Pea trials which were dressed with radio-active Ore showed considerable superiority over those grown in plain soil, but the cost of the Ore far outweighed the worth of the larger crop.

The quantity and degree of radio-active material required to ensure the best return cannot be definitely stated, but the experiments certainly indicated that a light dressing is likely to give as good results as a heavy one.

In the trials with Rape seed, the influence of the radio-active material in accelerating germination was most consistent in all the tests, but it was evident that a very small quantity of low-grade Residue proved as effective as a much greater amount of Ore containing a far larger proportion of Radium.

In the germinating tests in the laboratory also there was no indication that better results are obtainable with Ore possessing considerable radio-activity than with Residue of low value, nor did these trials generally prove superior to the "Controls."

With all but two of the consignments of radio-active material particulars were furnished of the approximate amount of Radium Bromide each contained per ton, and by careful calculation it was therefore possible to ensure an equal application of Radium in almost every case. In the two instances where the degree of radio-activity was not stated, the material was used at the strength recommended by the vendors.

It was clearly demonstrated in the 1914 experiments that, so far as any beneficial result was obtained, a weak dressing of radio-active Ore was quite as effective as a strong one, and this was taken into consideration in fixing the standard for the 1915 tests. For the trials in pots (Series 1) the dressing given was approximately 1/4,000th of a milligramme of Radium Bromide to a 10-inch pot containing about 15 lbs. of soil. In the open-ground plots (Series 2) the materials, in the foregoing ratio, were lightly forked into the top three inches of soil.

For comparative purposes suitable "Controls" were arranged (generally in duplicate). Where Farmyard Manure or Complete Fertiliser was added, the amount applied was such as is usually recommended for good average cultivation.

Those who possess a knowledge of Radium are aware that the Ores often contain many other chemicals or agents in addition to Radium, and it had been suggested to me on several occasions that these impurities, if I may so term them, might to some degree vitiate the results of these experiments owing to the fact that small quantities of copper sulphide and arsenic are sometimes present. Having secured, in confidence, the analysis of one of the Ores, showing the approximate percentage of impurities it was known to contain, I succeeded in obtaining a sufficient quantity of each impurity, to allow of a prescription being prepared which corresponded as nearly as possible to the original Ore, without of course the Radium. This prescription is referred to as "Chemical Mixture." In this connection I should like to acknowledge my indebtedness to Professor Duffield, B.A., D.Sc., of University College, Reading, for his valuable assistance. I also procured a supply of pure Radium Bromide, which obviously contained no foreign agent that could have an injurious effect upon plant life, and the tests made with it show some extremely interesting results.

The proprietary radio-active fertilisers named in the list on page 4 were included in these experiments solely for the purpose of obtaining information as to their respective values, and I have no wish to comment favourably or adversely concerning either of them.

The inclusion of coal dust in the list of dressings is due to the fact that a purchaser of the preparation known as Lignite is instructed to mix it with coal dust before application, and I was anxious therefore to test the comparative value of coal dust itself.

Statements have been made in America and elsewhere that a noticeable change is to be detected in the flavour of certain vegetables when grown in ground dressed with radio-active Ore. One report is to the effect that Vegetable Marrows so grown possess a distinct flavour of Pine Apple! In order to obtain an authoritative opinion on this point I approached Dr. Keeble, F.R.S., Director of the Royal Horticultural Gardens, Wisley (to whom I am greatly indebted for much valuable advice from time to time in connection with these experiments), who kindly undertook to cook and taste some Marrows for me. Dr. Keeble informed me that he could find nothing in the flavour of any of the Marrows grown with radio-active Ores markedly different from that of others.

In the course of these researches I have naturally been brought into touch with many others who are interested in the question of radio-active fertilisers. One correspondent suggested that the danger of using radio-active Ores containing chemicals of an injurious character could be eliminated by the employment of double-walled pots, by which means the Ore would be prevented from coming into contact with the soil.

Professor Rusby, of Columbia University, U.S.A., has written me several most interesting letters, in one of which he expressed the opinion that if Radium is of value at all to plant life, it is as a stimulant rather than a fertiliser. With this I entirely agree.

Monsieur Truffaut, of Paris, in reporting upon his own experiments, suggested that Radium might possess the power of releasing additional nitrogen in the soil for the use of plants, and stated that those plants which had received the largest dressing of radio-active material were found to suffer most from an excess of nitrogen, to the point in some cases of killing them.

It will be noticed that in several of my experiments plants dressed with a Complete Fertiliser, in addition to Radium, have not done so well as those dressed with the Fertiliser only, and this may perhaps be regarded as some corroboration of Monsieur Truffaut's conclusions.

As is invariably the case in experimental work, many contradictory results will be found in the following pages, and a close examination of the trial notes together with the records of weights will furnish many highly interesting problems.

In certain sections the result given by the duplicate "Control (unmanured)" varies considerably from that of the first "Control (unmanured)." This is, I am aware, a factor which all experimenters have to contend with. It has, however, been suggested to me that in the present case the divergence may be due to Radium emanations, and in view of the relative positions occupied by the "Controls" there may be some ground for the idea.



A portion of the Trials lifted for inspection.

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The Experiments in 1915 were divided into two main series.

SERIES 1. TRIALS WITH TOMATOES, POTATOES, RADISHES, and LETTUCES.

All the plants were grown in ten-inch pots, the total number of pots being 736. Each of the four subjects was grown in

- (a) Silver sand.
- (b) Unmanured soil sterilised at 200° Fahr.
- (c) Sterilised soil to which Farmyard Manure had been added.

The three sets were each dressed with various radio-active materials, as nearly as possible at a ratio of 1/4,000th of a milligramme of Radium Bromide per pot, thoroughly incorporated with the sand or soil. All the pots were sunk into the ground. Plain tap water was given, as required, and in other respects the whole of the plants of each subject received equal treatment.

Suitable "Controls" were arranged in duplicate, one set being placed at each end of the various sections.

Detailed tables, together with notes on the trials, are given on pages 8 to 13.

SERIES 2. TRIALS WITH VEGETABLE MARROWS, CARROTS, ONIONS, and SPINACH BEETS.

In this series the plants were grown in open-ground plots, to which no manure had been applied for some years previously, the total area being 216 square yards. Each plot, containing 18 square yards (about $\frac{1}{10}$ th of an acre), was divided into four equal sections, and sown in due course with seeds of the four subjects named above.

The various radio-active materials, each applied in an approximately equal degree of strength, were lightly forked into the top three inches of soil. In addition, a dressing of Complete Fertiliser was given to one half of the section devoted to each subject. Radium was therefore tested on plants growing (a) in unmanured soil, and (b) in soil to which a Complete Fertiliser had been added. For comparative purposes, "Control" plots were also sown.

Detailed tables, together with notes on the trials, are given on pp. 14 to 17.

In addition to the foregoing, sundry experiments were made with Mustard and Antirrhinums grown in double pots, and also to test the action of Radium on the germination of Rape seed. See pages 18 and 19.

SERIES 1.

EXPERIMENTS WITH TOMATOES.

Variety—Sutton's Early Market. Planted May 27.

Each trial consisted of four pots.

MATERIAL USED.	Approximate COST of dressing 4 pots.	WEIGHT OF FRUIT.		
		Grown in SAND.	Grown in STERILISED SOIL.	Grown in Sterillised Soil with Farmyard Manure added at a cost of $\frac{1}{2}$ d. per 4 pots.
FIRST CONTROL (unmanured)	—	lb. oz. 9	lb. oz. 1 11	lb. oz. —
FIRST CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	2 3	2 12	—
FIRST CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{2}$ d.	5 5	3 10	—
LIGNAITE	$1\frac{1}{2}$ d.	10	3 7	3 8
COAL DUST	$\frac{1}{4}$ d.	13	3 12	2 3
NIRAMA	$1/1\frac{1}{2}$ d.	1 12	3 0	6 3
VANADIUM SAND ..	2d.	1 5	4 3	4 15
McARTHUR'S SAND ..	$1\frac{1}{2}$ d.	11	5 13	5 8
SLIME, or MINE RESIDUE	$3\frac{3}{4}$ d.	9	3 13	5 0
ORE B	$4\frac{1}{2}$ d.	1 2	4 7	5 8
PITCHBLEND CONCENTRATES	5d.	2 0	5 14	5 3
ORE A	$3\frac{1}{2}$ d.	12	5 6	4 5
PURE RADIUM BROMIDE	$4\frac{1}{2}$ d.	1 3	3 15	5 3
DUPLICATE CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{2}$ d.	6 1	4 6	—
DUPLICATE CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	4 8	4 14	—
DUPLICATE CONTROL (unmanured)	—	13	6 15	—
CHEMICAL MIXTURE ..	—	9	3 5	—
COMPLETE FERTILISER and PURE RADIUM BROMIDE	$5\frac{1}{2}$ d.	3 14	4 6	—

For Trial Notes see next page.

SERIES 1—continued.

NOTES ON TOMATO EXPERIMENTS.

Twelve days after planting, all the trials dressed with Complete Fertiliser showed greener and healthier growth than the remainder.

TRIALS IN SAND.

Notes during Growth.—The two Controls dressed with Complete Fertiliser were distinctly the strongest and best fruited plants, one set being exceptionally good. Next in order of merit came the two Controls dressed with Farmyard Manure and the trial with Complete Fertiliser and Radium Bromide, between which little difference could be seen.

The weakest and least-fruited were the First Control (unmanured) and the trial with Chemical Mixture.

Between the remainder (most of which were dressed with Radium) there was not much to choose, except that the Pitchblende Concentrates section was the strongest.

The fact that the trial dressed with Complete Fertiliser and Radium Bromide was not so good as that where the Fertiliser was used alone, may perhaps indicate that the effect of the Fertiliser had been neutralised by the addition of Radium.

Final Notes.—The unmanured Controls gave 9 ozs. and 13 ozs. of fruit respectively. Five trials with radio-active materials alone exceeded the higher of these weights, the best (Pitchblende Concentrates) being 2 lbs. The Duplicate Control with Complete Fertiliser gave a yield of 6 lbs. 1 oz., and the Duplicate Control with Farmyard Manure 4 lbs. 8 ozs.

TRIALS IN SOIL.

Notes during Growth.—On the whole the plants did well. Some appeared to thrive better in untreated soil, or in soil and Radium, than in soil to which both Radium and Farmyard Manure had been added. In the last named section it may be that the plants suffered from over-feeding, through some possible action of the Radium on the manure.

Six of the trials dressed with Radium (without manure) were among the strongest and best fruited, but these were equalled by the Controls dressed with Fertiliser and with Farmyard Manure. The Duplicate Control (unmanured) was superior to all other sections, probably as the result of Radium emanations.

The weakest were First Control (unmanured) and the trial with Chemical Mixture.

Final Notes.—Taking the Duplicate Control (unmanured) as the standard, it cannot be said that any of the plants growing in sterilised soil benefited by the addition of Radium. But if the standard be set by the First Control (unmanured) then Radium would appear to have proved beneficial. The weight of fruit gathered from the unmanured Controls, however, shows such a wide divergence (First) 1 lb. 11 ozs. (Duplicate) 6 lbs. 15 ozs. (the heaviest yield of any section), that it is difficult to form any definite conclusion.

6 lbs. 1 oz. 4 lbs. 8 ozs. 2 lbs. 1 lb. 3 ozs. 13 ozs. 9 ozs. 9 ozs.



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DRESSING } Complete
USED. } Fertiliser.

Farmyard
Manure.

Pitchblende
Concentrates.

Pure
Radium
Bromide.

Coal
Dust.

Chemical
Mixture.

Plain
Sand.

Tomatoes grown in Sand.

SERIES 1—continued.

EXPERIMENTS WITH POTATOES.

Variety—Sutton's Edinburgh Castle. Planted April 24.

*Only one shoot was retained on each tuber.**Each trial consisted of four pots.*

MATERIAL USED.	Approximate COST of dressing 4 pots.	WEIGHT OF TUBERS.		
		Grown in SAND.	Grown in STERILISED SOIL.	Grown in Sterilised Soil with Farmyard Manure added at a cost of $\frac{1}{4}$ d. per 4 pots.
		lb. oz.	lb. oz.	lb. oz.
FIRST CONTROL (unmanured)	—	8 9	12 8	—
FIRST CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	13 4	13 2	—
FIRST CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{4}$ d.	13 5	16 4	—
LIGNAITE	$1\frac{1}{2}$ d.	10 14	12 1	13 1
COAL DUST	$\frac{1}{4}$ d.	10 10	10 12	9 10
NIRAMA	$1\frac{1}{4}$ d.	7 6	12 2	14 0
VANADIUM SAND ..	2d.	10 15	13 1	11 10
McARTHUR'S SAND ..	$1\frac{1}{2}$ d.	10 1	13 4	12 0
SLIME, or MINE RESIDUE	$3\frac{3}{4}$ d.	10 0	9 11	13 9
ORE B	$4\frac{1}{2}$ d.	8 8	9 8	10 6
PITCHBLEND CONCENTRATES	5d.	11 2	9 7	11 4
ORE A	$3\frac{1}{2}$ d.	9 2	9 3	11 0
PURE RADIUM BROMIDE	$4\frac{1}{4}$ d.	9 1	7 3	7 12
DUPLICATE CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{4}$ d.	13 14	14 2	—
DUPLICATE CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	13 12	12 1	—
DUPLICATE CONTROL (unmanured)	—	6 5	10 3	—
CHEMICAL MIXTURE ..	—	5 13	11 7	—
COMPLETE FERTILISER and PURE RADIUM BROMIDE	$5\frac{1}{4}$ d.	12 12	10 1	—

For Trial Notes see next page.

SERIES 1—continued.

NOTES ON POTATO EXPERIMENTS.

The tubers planted in sand showed signs of growth before those set in soil, but the shoots were weak.

A month after planting, the most forward sections were those dressed with Coal Dust and with Lignaite. A fortnight later, however, they had dropped behind, and the most robust foliage was seen in the trials dressed with Complete Fertiliser.

In these trials also it was noticed that some plants growing in soil treated with Radium only were superior to those dressed with Radium and Farmyard Manure.

TRIALS IN SAND.

Notes during Growth.—When in full growth the plants with the strongest foliage were found in the following sections: Complete Fertiliser and Pure Radium Bromide, Controls with Complete Fertiliser and with Farmyard Manure, Vanadium Sand, McArthur's Sand, and Pitchblende Concentrates.

The weakest plants were those dressed with Chemical Mixture and with Pure Radium Bromide only.

Between the remaining trials growing in sand it was difficult to observe any difference.

The unmanured Controls were especially good, considering that the plants were growing in pure sand, but this is due to the fact that the Potato plant can live for a long period on its own tuber.

Final Notes.—The weights obtained from the unmanured Controls were (First) 8 lbs. 9 ozs. and (Duplicate) 6 lbs. 5 ozs. Seven of the trials dressed with radio-active materials only gave a larger return than the First Control (unmanured). The heaviest sections were the four Controls dressed with Complete Fertiliser and with Farmyard Manure, with weights ranging to 13 lbs. 14 ozs., followed by Complete Fertiliser and Pure Radium Bromide which gave 12 lbs. 12 ozs.

TRIALS IN SOIL.

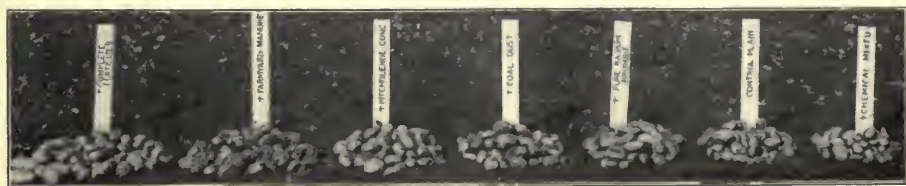
Notes during Growth.—It was noticeable that in all the sections to which Farmyard Manure had been applied the foliage of the plants was paler in colour than in the remainder. In the trials dressed with Complete Fertiliser, the foliage exhibited a much bluer tinge than in any of the others, and the plants were more branching in habit.

At the period of full growth the strongest sections were the Controls dressed with Complete Fertiliser, closely followed by Complete Fertiliser and Pure Radium Bromide. The next best were the Farmyard Manure Controls, and the tests with Nirama and McArthur's Sand.

The weakest plants were those treated with Pure Radium Bromide alone.

Final Notes.—There was a yield of 12 lbs. 8 ozs. from First Control (unmanured), and from the Duplicate set 10 lbs. 3 ozs., and the first-named weight was exceeded in only two sections where Radium was used without manure. The best weights were 16 lbs. 4 ozs. and 14 lbs. 2 ozs., from the Controls dressed with Complete Fertiliser, and the lowest (7 lbs. 3 ozs.) from the Pure Radium Bromide test.

13 lbs. 14 ozs. 13 lbs. 12 ozs. 11 lbs. 2 ozs. 10 lbs. 10 ozs. 9 lbs. 1 oz. 8 lbs. 9 ozs. 5 lbs. 13 ozs.



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DRESSING } Complete
USED. } Fertiliser.

Farmyard
Manure.

Pitchblende
Concentrates.

Coal
Dust.

Pure
Radium
Bromide.

Control,
Unmanured.

Chemical
Mixture.

Potatoes grown in Sand.

SERIES 1—continued.

EXPERIMENTS WITH RADISHES.

Variety—Sutton's Scarlet Globe. Sown August 23.

Each trial consisted of four pots.

MATERIAL USED.	Approximate COST of dressing 4 pots.	WEIGHT OF PRODUCE.		
		Grown in SAND.	Grown in STERILISED SOIL.	Grown in Sterilised Soil with Farmyard Manure added at a cost of $\frac{1}{2}$ d. per 4 pots.
FIRST CONTROL (unmanured)	—	oz. 2	lb. oz. 1 2	lb. oz. —
FIRST CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	12	2 1	—
FIRST CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{4}$ d.	$14\frac{1}{2}$	2 $12\frac{1}{2}$	—
LIGNAITE	$1\frac{1}{2}$ d.	5	$15\frac{1}{2}$	1 $11\frac{1}{2}$
COAL DUST	$\frac{1}{4}$ d.	4	1 0	1 $14\frac{1}{2}$
NIRAMA	$1\frac{1}{2}$ d.	$4\frac{1}{2}$	1 $2\frac{1}{2}$	2 1
VANADIUM SAND ..	2d.	3	1 6	1 15
McARTHUR'S SAND ..	$1\frac{1}{2}$ d.	$3\frac{1}{2}$	1 2	2 3
SLIME, or MINE RESIDUE	$3\frac{3}{4}$ d.	3	13	1 $12\frac{1}{2}$
ORE B	$4\frac{1}{2}$ d.	4	1 8	2 2
PITCHBLEND CONCENTRATES	5d.	4	1 6	2 $0\frac{1}{2}$
ORE A	$3\frac{1}{2}$ d.	$4\frac{1}{2}$	1 4	1 $13\frac{1}{2}$
PURE RADIUM BROMIDE	$4\frac{1}{4}$ d.	$2\frac{1}{2}$	1 $2\frac{1}{2}$	1 13
DUPLICATE CONTROL (dressed with Complete Fertiliser)	$1\frac{1}{4}$ d.	$8\frac{1}{2}$	2 $5\frac{1}{2}$	—
DUPLICATE CONTROL (dressed with Farmyard Manure)	$\frac{1}{2}$ d.	$13\frac{1}{2}$	1 $14\frac{1}{2}$	—
DUPLICATE CONTROL (unmanured)	—	3	1 5	—
CHEMICAL MIXTURE ..	—	3	1 6	—
COMPLETE FERTILISER and PURE RADIUM BROMIDE	$5\frac{1}{2}$ d.	$9\frac{1}{2}$	2 $0\frac{1}{2}$	—

For Trial Notes see next page.

SERIES 1—continued.

NOTES ON RADISH EXPERIMENTS.

Within a week from date of sowing the trials in soil dressed with Lignaite, Coal Dust, Nirama, Slime or Mine Residue, Pitchblende Concentrates, Ore A, and Pure Radium Bromide, showed an undoubted superiority in strength of growth over all others, although there was little difference to be observed between any of those named.

TRIALS IN SAND.

Notes during Growth.—All the plants were extremely weak. The Controls dressed with Farmyard Manure and with Complete Fertiliser produced the sturdiest foliage.

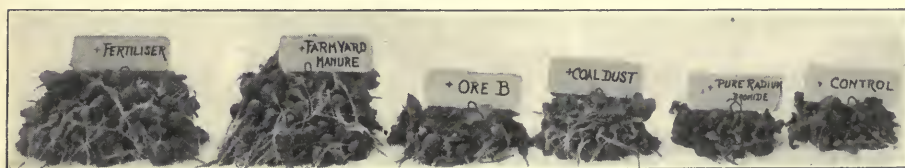
Final Notes.—On weighing the roots the yield from the unmanured Controls was 2 ozs. and 3 ozs. respectively. From the pots dressed with radio-active materials the weights varied from $2\frac{1}{2}$ ozs. to 5 ozs., thereby claiming some slight advantage. But all were far below the First Control dressed with Complete Fertiliser with $14\frac{1}{2}$ ozs., and the Duplicate Control dressed with Farmyard Manure with $13\frac{1}{2}$ ozs.

TRIALS IN SOIL.

Notes during Growth.—It was a very difficult matter to distinguish a difference in the strength of the foliage of plants growing in the unmanured Controls and in the tests with radio-active materials (unmanured). The strongest plants, and the earliest to form roots, were those in the Farmyard Manure Controls and in the sections where Complete Fertiliser was used. In the trials dressed with Complete Fertiliser the foliage was of a deeper colour.

Final Notes.—From the First Control (unmanured) roots weighing 1 lb. 2 ozs. were lifted, and from the Duplicate Control 1 lb. 5 ozs. The latter figures were exceeded in only three instances where radio-active materials (without manure) were used, the best of which (Ore B) being 1 lb. 8 ozs.

First Control with Complete Fertiliser topped the table with 2 lbs. $12\frac{1}{2}$ ozs., the second being Duplicate Control with Complete Fertiliser, 2 lbs. $5\frac{1}{2}$ ozs., and third, First Control with Farmyard Manure, 2 lbs. 1 oz.



14 $\frac{1}{2}$ ozs.

13 $\frac{1}{2}$ ozs.

4 ozs.

4 ozs.

2 $\frac{1}{2}$ ozs.

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3 OZS.

Radishes grown in Sand.

EXPERIMENTS WITH LETTUCES.

Adverse climatic and other conditions so affected these trials that the heads did not mature. No weights were therefore recorded.

SERIES 2.

EXPERIMENTS WITH VEGETABLE MARROWS.

Variety—Sutton's Tender and True. Sown May 11.

MATERIAL USED.	Approximate COST of dressing 2½ square yards.	WEIGHT OF FRUIT.	
		From open ground plots, each 2½ square yards.	From open ground plots, each 2½ square yards, to which Com- plete Fertiliser to the value of about 1d. had been applied.
		lb. oz.	lb. oz.
FIRST CONTROL (unmanured)	—	14 7	—
CONTROL (dressed with Farmyard Manure)	1½d.	22 14	—
CONTROL (dressed with Complete Fertiliser)	1½d.	31 0	—
LIGNAITE	1/1½d.	22 4	18 8
COAL DUST	2¼d.	26 12	23 0
NIRAMA	1/1½d.	18 4	15 2
VANADIUM SAND ..	3d.	11 8	18 2
McARTHUR'S SAND ..	2½d.	21 10	11 12
SLIME, or MINE RESIDUE	5d.	14 10	20 8
DUPLICATE CONTROL (unmanured)	—	21 12	—
ORE B	7½d.	17 11	16 8
PITCHBLEND CONCENTRATES	8¼d.	21 7	22 6
ORE A	5¾d.	18 0	30 4
PURE RADIUM BROMIDE	6¼d.	16 0	21 10

Notes during Growth.—Germination was strong and even in all sections. Four weeks after sowing, growth was strongest in Farmyard Manure Control, which was only slightly superior to the Complete Fertiliser Control. A month later saw the positions reversed, and the plants in the Complete Fertiliser Control were not only the most healthy but were producing the greatest number of fruits.

The poorest trials were First Control (unmanured) and Pure Radium Bromide.

Plots dressed with Complete Fertiliser in addition to Radium did not produce stronger growth than those which received no Fertiliser. In no case did the plants in plots dressed with Radium alone, or with Radium and Complete Fertiliser, appear so robust as those in the Complete Fertiliser Control.

Final Notes.—From the unmanured Controls the produce weighed (First) 14 lbs. 7 ozs., (Duplicate) 21 lbs. 12 ozs., and the latter was exceeded by only one section dressed with radio-active material (unmanured). The greatest weight was realised from the Complete Fertiliser Control, viz., 31 lbs.

SERIES 2—continued.

EXPERIMENTS WITH CARROTS.

Variety—Sutton's Scarlet Intermediate. Sown April 26.

MATERIAL USED.	Approximate COST of dressing 2½ square yards.	WEIGHT OF PRODUCE.	
		From open ground plots, each 2½ square yards.	From open ground plots, each 2½ square yards, to which Com- plete Fertiliser to the value of about 1d. had been applied.
FIRST CONTROL (unmanured)	—	lb. oz. 11 11	lb. oz. —
CONTROL (dressed with Farmyard Manure)	1½d.	15 14	—
CONTROL (dressed with Complete Fertiliser)	1½d.	13 8	—
LIGNAITE	1/1½d.	11 8	11 4
COAL DUST	2½d.	11 0	13 2
NIRAMA	1/1½d.	12 12	12 10
VANADIUM SAND ..	3d.	12 14	11 4
McARTHUR'S SAND ..	2½d.	11 12	17 0
SLIME, or MINE RESIDUE	5d.	10 6	11 10
DUPLICATE CONTROL (unmanured)	—	12 7	—
ORE B	7½d.	13 2	14 10
PITCHBLEND CONCENTRATES	8½d.	11 8	12 0
ORE A	5½d.	11 10	11 14
PURE RADIUM BROMIDE	6½d.	12 10	13 0

Notes during Growth.—The plots dressed with Pure Radium Bromide showed the most even germination, but the plants were weaker than in some others. Two months from date of sowing, the Farmyard Manure Control presented the strongest foliage, but was only slightly superior to the trials dressed with Ore B. The unmanured Controls were the weakest of any.

By mid-August, Farmyard Manure Control was still ahead of all others; the weakest in growth being First Control, Lignaite, Coal Dust, Slime or Mine Residue, Ore A, and Pure Radium Bromide.

No appreciable difference could be seen in the foliage of any of the plants, whether treated with Radium only or with Radium and Complete Fertiliser, and certainly none of these trials appeared so strong and healthy as the Farmyard Manure Control.

Final Notes.—The weight of roots lifted from the First Control (unmanured) was 11 lbs. 11 ozs., and from the Duplicate Control 12 lbs. 7 ozs. The latter weight was surpassed in four of the trials dressed with radio-active materials (unmanured). Farmyard Manure Control gave far the best return with 15 lbs. 14 ozs., Complete Fertiliser Control being second with 13 lbs. 8 ozs.

SERIES 2—continued.

EXPERIMENTS WITH ONIONS.

Variety—Sutton's Improved Reading. Sown April 26.

MATERIAL USED.	Approximate COST of dressing 2½ square yards.	WEIGHT OF PRODUCE.	
		From open ground plots, each 2½ square yards.	From open ground plots, each 2½ square yards, to which Com- plete Fertiliser to the value of about 1d. had been applied.
		lb. oz.	lb. oz.
FIRST CONTROL (unmanured)	—	11 6	—
CONTROL (dressed with Farmyard Manure)	1½d.	21 3	—
CONTROL (dressed with Complete Fertiliser)	1½d.	19 10	—
LIGNAITE	1/1½d.	12 6	12 2
COAL DUST	2½d.	8 4	6 12
NIRAMA	1/1½d.	11 10	19 4
VANADIUM SAND ..	3d.	20 8	22 8
McARTHUR'S SAND ..	2½d.	21 4	20 4
SLIME, or MINE RESIDUE	5d.	21 4	21 0
DUPLICATE CONTROL (unmanured)	—	21 2	—
ORE B	7½d.	22 6	19 0
PITCHBLEND CONCENTRATES	8½d.	23 4	21 4
ORE A	5½d.	18 6	17 6
PURE RADIUM BROMIDE	6½d.	6 6	10 2

Notes during Growth.—Signs of vitality were first seen in the Farmyard Manure Control and in the plots dressed with Coal Dust, Nirama, and Ore B, but the most regular germination was found in the tests with Pure Radium Bromide.

Two months after date of sowing, Farmyard Manure Control was most uniformly strong in top growth, the unmanured First Control and Pure Radium Bromide being weakest.

A month later, Farmyard Manure Control still held first place, but there had been considerable improvement in the plots dressed with Vanadium Sand, McArthur's Sand, Slime or Mine Residue, Ore B, and Pitchblende Concentrates, in which the plants were now almost equal to the Farmyard Manure Control. The Duplicate Control (unmanured) had also made great progress and was but little inferior to any of the foregoing. This, however, was somewhat curious in view of the fact that in the experiments with Vegetable Marrows, Spinach Beets, and Carrots, the Duplicate Controls had not improved to the same extent.

SERIES 2—continued.

NOTES ON ONION EXPERIMENTS—continued.

Where Complete Fertiliser had been applied in addition to radio-active materials, the effect was visible only in the tests with Nirama, Vanadium Sand, and McArthur's Sand, in which the foliage was of a darker green.

In the experiments with Onions there was evidence that the plants in most of the plots dressed with radio-active materials only were equally as strong as those in the Farmyard Manure and Complete Fertiliser Controls.

Final Notes.—There was a considerable difference in the weights obtained from the unmanured Controls, the First yielding 11 lbs. 6 ozs. and the Duplicate 21 lbs. 2 ozs. The best returns were from four plots dressed with radio-active materials, but on the other hand, the lowest weight of any was 6 lbs. 6 ozs. from the test with Pure Radium Bromide (unmanured).

As, however, the unmanured Controls gave such widely varying results (as also was the case with the Tomato trials in soil), no very definite conclusions from the tests with Onions can be formed.

NOTES ON EXPERIMENTS WITH SPINACH BEETS.

Seed sown April 26.

The first plot to germinate was that dressed with Nirama, while that which was treated with Pure Radium Bromide showed the most even vitality.

Within two months from time of sowing, the Complete Fertiliser Control held first place, and this was followed closely by the Farmyard Manure Control. The next best were the plots dressed with Lignite and Coal Dust. First Control (unmanured) and Pure Radium Bromide were the weakest in growth.

Four weeks later Farmyard Manure Control had taken the lead. At this stage, the sections dressed with Complete Fertiliser in addition to the radio-active materials showed, in most cases, to greater advantage than the trials with Radium only. This improvement was especially noticeable in the tests with Ore A, Ore B, and Pitchblende Concentrates, where the leaves were very green and healthy.

By the middle of August the condition of several plots had changed. Farmyard Manure Control was still strongest in growth, with Complete Fertiliser Control and the Lignite trial equal for second place. Some of the plants in the unmanured Duplicate Control, which had greatly improved, were as robust as those in the Farmyard Manure Control. First Control (unmanured) and Pure Radium Bromide remained the weakest.

In no instance were the plants in the plots treated with radio-active materials alone so good as those in the Farmyard Manure and Complete Fertiliser Controls. Neither were the trials grown with Radium and Complete Fertiliser together better than the Controls with Manures alone.

No weights were taken of the Spinach Beet trials, but the most luxuriant growth was produced in the Farmyard Manure and Complete Fertiliser Controls.

SUNDRY EXPERIMENTS.

TRIALS WITH MUSTARD AND ANTIRRHINUMS GROWN IN SINGLE AND DOUBLE POTS.

The object of these trials was to ascertain the effect of Radium on plant life when the radio-active Ores were not brought into actual contact with the roots. The means adopted was to place a 10-inch pot containing plants into a pot of the 12-inch size, and to fill in the intervening space with radio-active Ore of about the same degree of strength as used in the experiments already described. For comparison, plants of each subject were grown in single pots containing (a) plain soil, (b) soil and Complete Fertiliser, (c) soil and radio-active Ores, (d) soil, Complete Fertiliser, and radio-active Ores. Where the double pots were used, the subjects were planted in (a) plain soil, and (b) soil and Complete Fertiliser.



Experiments with Mustard.

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Single pot.
Plain soil.

Single pot.
Dressed with
Radium.

Double pot.
Plain soil.
Radium
between pots.

Single pot.
Dressed with
Complete
Fertiliser.

Single pot.
Dressed with
Complete
Fertiliser and
Radium.

Double pot.
Dressed with
Complete Fertiliser.
Radium
between pots.

TRIAL NOTES ON MUSTARD. Seed sown September 1.

The first signs of germination were visible on September 6 in the single pots dressed with Radium (one of which contained a proportion of Pure Radium Bromide), and in the double pots where Complete Fertiliser had been incorporated with the soil. The double pots with Radium between, and filled with plain soil, were a day later in germinating.

By September 10 the most forward plants were found in the double pots dressed with Complete Fertiliser. Next in order came those in the single pots containing a proportion of both Radium and Complete Fertiliser.

On September 15 the plants growing in plain soil in single pots had improved and were stronger than those treated with Radium (unmanured), whether mixed with the soil or placed between pots. The trials in double pots (unmanured) showed greater strength than those in the unmanured single pots containing Radium. But the strongest of all were in the single pots dressed with Complete Fertiliser only.

TRIAL NOTES ON ANTIRRHINUMS.

The plants were potted on June 14, and by the end of July those which had received a dressing of Complete Fertiliser were decidedly superior to the others. In no instance was any advantage from the use of Radium observed, whether the material was incorporated with the soil or placed between pots. At the end of September the condition of the plants was relatively the same.

NOTES ON THE GERMINATION OF MUSTARD SEED.—In the 1914 experiments it was found that the germination of Rape seed was accelerated by dressings of radio-active Ore, and that a light dressing was apparently as effective as a heavier one. There was, of course, the possibility that germination might have been influenced by chemicals other than the Radium contained in the various Ores. But it is interesting to note that in some tests made in 1915 with Mustard, the seeds sown in pots dressed with Pure Radium Bromide were among the first to start into growth, which apparently shows that accelerated germination is due to Radium and not to impurities in the Ores. The influence of the Radium on the Mustard plants, however, was not maintained beyond the development of the second leaf.

EXPERIMENTS WITH RAPE SEED to ascertain the effect on germination.

These tests were made in ten large boxes, each three feet square by six inches deep, filled with unsterilised soil. Only one kind of radio-active material (Ore B) was used (a) incorporated with the soil, (b) enclosed in an earthenware cylinder and inserted in centre of box, (c) enclosed in a glass bottle and inserted in centre of box. These three methods were repeated in boxes to which Complete Fertiliser was also added. The Controls consisted of plain soil (two boxes) and soil dressed with Complete Fertiliser (two boxes).

(It is probable that the A, B, and G rays are all capable of penetrating earthenware. But in the case of the glass bottles, Dr. Duffield is of the opinion that the A and B rays are entirely imprisoned, and only the G rays have power to act.)

NOTES ON THE TESTS.

The seeds were sown on August 20. Four days later every box showed the soil to be cracking and the germs breaking through.

On August 26 the box containing radio-active Ore mixed with soil possessed the strongest plants. Next in order came the trials with the Ore placed respectively in a cylinder and in a bottle, within a small radius of which the strong growth immediately arrested attention. Very little difference could be seen between the plain soil Controls, the Complete Fertiliser Controls, and the three boxes treated with Ore and Complete Fertiliser.

As the three tests with radio-active Ore alone were more forward in growth than those in which the Ore and Complete Fertiliser were used together, it is probable that the Ore and Fertiliser neutralised each other. A note on this point also appears under the Trials with Tomatoes, page 9.

August 27. The lead was held by the box containing the Ore mixed with soil. Plain Soil Controls appeared stronger than the three boxes treated with Ore and Complete Fertiliser.

September 1. The test with Ore mixed with soil was still the best. But growth was practically as strong around the cylinder and the bottle in the boxes not dressed with Complete Fertiliser, although these two boxes were not uniformly good. Between the remainder there was little difference.

September 15. By this date the Complete Fertiliser Controls were strongest, next to which came the tests with Ore mixed with soil, both with and without Complete Fertiliser.

In every instance where Complete Fertiliser had been used the plants exhibited darker foliage.



Experiments with Rape seed.

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CONCLUDING OBSERVATIONS.

Those of my readers who have had sufficient patience to closely examine the foregoing pages will probably agree with me that the experiments there described indicate no more hope of the successful employment of Radium as an aid to either Horticulture or Agriculture than did the trials I carried out in 1914.

In the conduct of scientific research, negative results sometimes prove as important as those which can be definitely affirmed; and while it would have afforded greater interest to have been able to establish contrary results to those recorded, I venture to hope that these experiments may have their value as the first extensive series of controlled trials undertaken in this country. Reporting on these tests *The Times* of September 25, 1915, states:—"If Mr. Sutton's investigations can be accepted as conclusive—and they are so regarded by competent botanists and chemists—the farmer and gardener need look for no material benefit from Radium. The chief result has been to emphasise the value of farmyard manure and complete artificial fertilisers. The lessons are of great importance to gardeners."

I am interested to observe that in some experiments of a more or less similar nature, recently conducted by Dr. Cyril Hopkins at the University of Illinois Experimental Station, U.S.A., equally negative results were obtained. The tests were made with Maize and Soya Beans, and the experimenter states that although the dressings varied in degree from 0.01 milligramme of Radium per acre to a hundred times that amount, in no case was a consistent increase in crop obtained.

It would therefore appear that the door is still open to the investigator in search of a plant fertiliser which will prove superior to farmyard dung or the many excellent artificial preparations now available.

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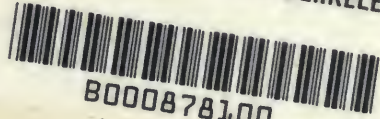
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